



DEVELOPMENT AND STRATEGIC FRAMEWORK OF THE MAIN CYCLING ROUTES NETWORK IN THE REPUBLIC OF CROATIA

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Abstract

Cycling is increasingly seen as a key component of sustainable and multimodal transport systems, owing to its benefits for the environment, public health, and mobility. In line with European environmental and transport policies, the Republic of Croatia has recognized cycling as an integral part of its national mobility system. Although the modal share has remained only slightly higher, there is still plenty of opportunity for development, and a comprehensive national approach must be designed. This study, additionally evaluates Croatia's current cycling networks and infrastructure, recommends an approach to improve a network that includes vital cycle routes. The proposed national network consists of ten state-level cycling corridors with a total length of approximately 4,300 km, integrated with international EuroVelo routes to ensure national and cross-border connectivity. The study focuses on the network's geographical configuration, a review of the present state of the current infrastructure, and the identification of the most significant planning and investment objectives necessary for developing a continuous and safe network of routes of national relevance. Using official national data and planning documents, the methodological approach is based on geographic analysis, functional route classification, and infrastructure quality and safety assessment. Emphasis is placed on the integration of national and European corridors and the identification of critical infrastructure gaps. The results provide a basis for future transport planning and investment decisions, supporting the development of low-carbon, safe, and resilient transport systems in accordance with European sustainable mobility objectives.

Keywords: cycling infrastructure, national routes, EuroVelo, sustainable mobility

1 Introduction

Because of its benefits for public health, environmental sustainability, and urban quality of life, cycling has become a central element of sustainable mobility policies. At the European level, it is increasingly recognised as a strategic mode of transport with the capacity to reduce greenhouse gas emissions, alleviate traffic congestion, and improve accessibility. Through the adoption of the National Cycling Development Plan for the period 2023–2027, the Republic of Croatia has acknowledged cycling as a key component of its transport and mobility system. Despite Croatia's favourable geographic and climatic conditions, cycling still represents a relatively small share of overall travel demand compared to many European Union member states. This imbalance highlights significant untapped potential, particularly in urban and peri-urban areas and for short- and medium-distance trips. Accordingly, the development of a coherent and continuously improving national cycling network is essential to increasing cycling uptake and ensuring its effective integration into the wider transport system.

This paper seeks to advance this objective by assessing the current state of cycling infrastructure in Croatia and by proposing a strategic framework for the development of a comprehensive national cycling routes network. The analysis is based on official national datasets and planning documents, with a particular focus on identifying key infrastructure gaps, development priorities, and principles for implementation. The paper is structured as follows: it begins with a review of relevant literature and policy frameworks, followed by a description of the methodology and data sources, and an analysis of the evolution of the main cycling routes network. The paper concludes with a discussion of strategic implications and final conclusions.

2 Literature and policy overview

As a crucial element of low-carbon and sustainable mobility systems, the development of cycling infrastructure has drawn more attention in transportation research and policy. Cycling is no longer primarily framed as a leisure activity at the European level, it is now seen as an essential component of daily transportation that calls for careful planning, sustained funding, and robust institutional coordination [1, 2]. Recent planning approaches emphasize the importance of clearly defined cycling infrastructure typologies and functional classifications to ensure consistent planning and network development [3]. The Sustainable and Smart Mobility Strategy and the European Green Deal are two strategic policy documents that specifically support cycling as a space-efficient, low-carbon, and socially inclusive mode of transportation. They also encourage Member States to incorporate cycling infrastructure into their long-term mobility planning frameworks and national transportation systems [4, 5]. Building on this policy framework, research continuously shows that network coherence and connectivity are far more important for cycling infrastructure effectiveness than the discrete provision of individual facilities. Studies on the connectivity of bicycle networks reveal that disjointed networks with frequent discontinuities greatly impair usability and deter wider population adoption [6, 7]. To assess and improve cycling systems, network-based analytical techniques which are frequently bolstered by spatial analysis and graph-theoretical methods have been used increasingly [8]. These methods place a strong emphasis on identifying the primary cycling corridors that serve as the system's structural pillars and are bolstered by local and regional feeder routes.

Prioritizing investments has become a major area of study in cycling infrastructure planning. To guide infrastructure investment decisions, several studies suggest multi-criteria decision-making frameworks that incorporate demand potential, safety performance, network connectivity, and cost efficiency [9, 10]. These frameworks advance system-oriented, strategic network development beyond ad hoc project selection. According to recent review studies, giving high-impact corridors and missing links priority results in significantly larger network-level benefits than uniform or disorganized network expansion [11], which is especially important in situations with constrained financial resources. Research and policy recommendations on bicycle infrastructure place a high priority on safety factors. According to empirical data, cyclists are much less likely to sustain an injury on physically segregated cycling facilities than they are on painted on-road bike lanes or in mixed traffic conditions [12, 13]. This is especially crucial for major bike routes, which are often near areas with heavy traffic. The research repeatedly emphasizes the significance of perceived safety, which is crucial in influencing cycling behaviour and participation across various demographic groups, to quantify safety results objectively [14]. An economic analysis offers a compelling case for funding top-notch bicycle infrastructure. Cycle highways and other high-quality cycling corridors have consistently shown favourable benefit-cost ratios, mostly due to reduced travel times, improved public health, reduced emissions of greenhouse gases, and fewer expenses related to traffic accidents [15].

The findings back up the idea that bicycle infrastructure is a long-term, strategic public investment rather than an add-on or supplemental mode of transportation. National plans provide an important part in turning general objectives into specific, practical frameworks within the context of these increasingly comprehensive European policies. The first extensive attempt to systematize cycling development at the national level in Croatia is the National Cycling Development Plan 2023–2027. The plan emphasizes the need for a precise network for primary bicycle networks and provides an organized framework for infrastructure development, funding sources, and institutional responsibilities [16]. National safety figures point out the importance of such an organized strategy. Over the last ten years, the Republic of Croatia's traffic accident records record numerous cyclist-related accidents, most of which result in moderate or severe injuries, along with an average number of fatalities yearly [17]. The general percentage of cycling involvement in traffic accidents is continually high, despite annual changes, suggesting that the Croatian road system has a fundamental problem with cyclist safety. Cycling infrastructure development and route classification are additionally defined through national regulatory documents that prescribe technical standards for cycling infrastructure and the functional categorisation of cycling routes [18, 19].

3 Methodology and data

The analytical framework employed in the document Analysis of the State of Cycling Traffic in the Republic of Croatia, which was created as a part of the National Cycling Development Plan, provides a basis for the methodological approach used in this study. The analysis integrates qualitative evaluation of institutional arrangements and planning with quantitative data on infrastructure, investments, and safety. The modal share of cycling is an essential statistic in the analysis. According to available data, 6% of the total trips in Croatia are taken by bicycle, which is significantly lower than the EU average and considerably less than in nations with sophisticated cycling infrastructure.

A significant potential demand for cycling is shown from statistics on bicycle possession and purchases, which show a consistent rise in the number of bicycles, including an increasing proportion of electric bicycles. The evaluation of the current bicycle infrastructure is the main emphasis of the methodology. In 2021, there were roughly 714 km of bike infrastructure on state and county highways, according to national records. This data was gathered from local governments and road agencies and combined into a nationwide summary. An estimated 536 km of additional bike infrastructure will be built as part of planned investments until 2027, which will significantly expand the current network. A separate analysis of urban bicycle infrastructure was conducted using data from twenty-one cities. The overall length of cycling infrastructure in those cities was about 849 km, and a further 342 km are planned by 2027. A review of safety data, including the number of bicycles involved in traffic accidents, revealed that cyclists continue to be an at risk population, particularly in places with poor or inconsistent infrastructure. Priorities for the creation of a nationwide network of primary cycling routes are determined through an analysis of infrastructure, demand, and safety data.

4 Development of the main cycling routes network in Croatia

National and regional bicycle networks are commonly organised through a hierarchical structure that classifies routes according to their spatial importance and functional role. A bicycle route represents a corridor connecting key destinations and consists of road segments or dedicated infrastructure used in mixed traffic conditions. This classification distinguishes between secondary routes providing regional and local connections and primary routes of national importance forming the backbone of the cycling network. Such an approach supports consistent network development, investment prioritisation, and effective planning.

These routes are designed to serve as international and interregional corridors that connect important tourist attractions, cities, and regional hubs while maintaining safety and continuity, supporting the development of cycle tourism as an important component of regional tourism development [20]. A significant share of existing cycling infrastructure is located along state and county roads, but many of these parts have poor design quality and interruptions. By 2027, there will be about 295 km of new bicycle infrastructure along state roads thanks to planned investments, which could significantly increase interregional connection. By connecting smaller communities and offering access to the main routes, county and local roads play an essential supporting purpose. There are now approximately 278 km of cycling infrastructure along these roads, and another 241 km is planned. These routes are especially crucial for connecting local networks to the national system and for facilitating regular cycling in suburban and rural areas. Another essential component of the entire system is urban cycling networks. Although urban areas have a sizable amount of bike infrastructure overall, each city's level of development differs significantly. Urban networks are frequently made up of discrete parts rather than cohesive systems. Similar challenges related to the continuity and spatial organisation of cycling networks have also been identified in recent Croatian transport research [21]. Thus, one of the primary objectives is to improve the functional connection between urban networks and regional and national routes. The Danube Cycle Plans' four infrastructure categories, Assessment of cycling infrastructure and investment demands for DanuVelo methodology [21] were used to evaluate the state of the Republic of Croatia's primary state cycling routes.

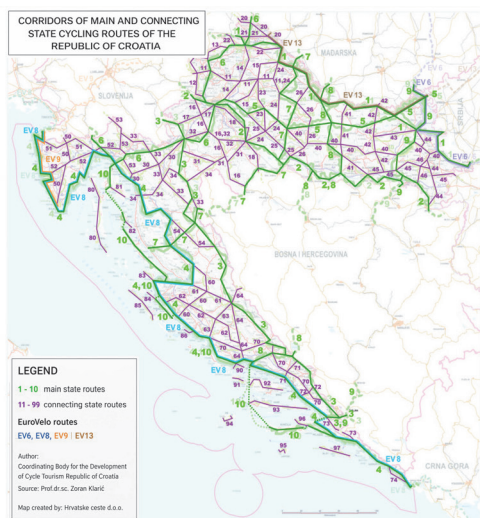


Figure 1 Corridors of main and connecting state cycling routes in the Republic of Croatia

Approximately 72% of the network length consists of routes classified as Good Enough Cycling Infrastructure (GECI), requiring minimal interventions (around EUR 1, 000 per kilometre). About 17% is categorized as Adjusting Existing Adequate Roads (AEAR), where minor modifications to the current road infrastructure are needed, with estimated costs of around EUR 10, 000 per kilometre. Construction Improvement Needed (CINE) represents roughly 3% of the network and indicates the need for more substantial infrastructure upgrades, estimated at about EUR 50, 000 per kilometre. New Cycling Infrastructure Needed (NECI) accounts for approximately 8% of the main state cycling routes, where entirely new facilities must be constructed, resulting in significantly higher costs of around EUR 282, 000 per kilometre.

This distribution suggests that while most of the network is in relatively good condition, a limited number of critical sections requiring major investments significantly influence total investment needs. Consequently, these sections should be prioritised in strategic planning and phased implementation. Current assessments also indicate considerable gaps along nationally important corridors due to the lack of continuous and well-designed cycling infrastructure.

A significant share of the route network still requires new construction or substantial upgrades to meet functional and safety standards, although some sections already include cycling facilities. The extent of missing links and the complexity of construction along state road corridors are reflected in the estimated investment needs, amounting to several million euros. The network's economic feasibility is supported by the average investment required per kilometre, which aligns with national cost estimates for cycling infrastructure development. Completing the main state cycling routes would improve continuity, safety, and regional connectivity, generating significant network-level benefits.

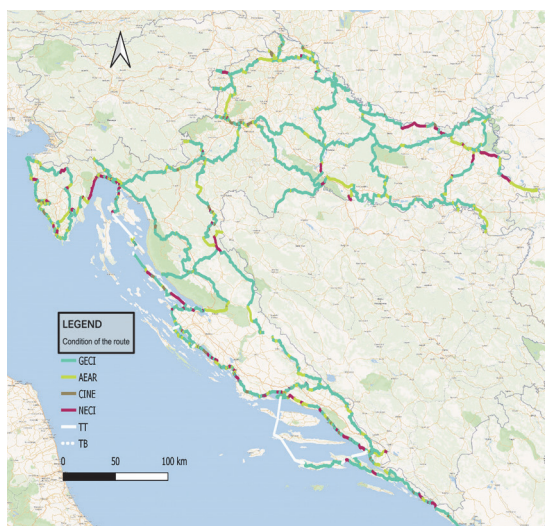


Figure 2 Condition assessment of main state cycling routes in the Republic of Croatia

The planned expansion of urban cycling infrastructure creates opportunities for a hierarchical network in which local routes connect to major national corridors. Construction costs vary depending on project type, location, and design characteristics. Available data indicate that average construction costs range from approximately EUR 90, 000 to over EUR 110, 000 per kilometre, with higher values typically associated with urban areas and projects along state roads due to spatial constraints, safety requirements, and additional infrastructure elements. In contrast, projects on county and municipal roads generally have lower unit costs because of fewer technical limitations and simpler design solutions. Investment estimates also show that a significant share of funding is directed toward projects addressing key gaps in the national and regional cycling network rather than isolated local improvements. Overall, the cost analysis highlights the importance of prioritising projects that maximise network connectivity and functional benefits while confirming that the planned expansion represents a substantial, yet proportionate investment compared with similar European initiatives.

5 Strategic framework and implementation plan

Integration, priority, and phased implementation provide the strategic framework for the growth of Croatia's primary network of cycling routes. Integration is the process of coordinating national bike routes with public transportation systems, regional mobility plans, and urban mobility plans. Closing vital network gaps, enhancing security on high-risk areas, and maintaining continuity throughout major routes are the key goals of prioritization. Phased implementation is planned, with short-term initiatives focusing on dangerous areas and missing links and medium- to long-term initiatives concentrating on network standardization and growth. For implementation to be successful, national authorities, county road administrations, and local governments must institutionally coordinate. It is expected that financing will be provided by a combination of national and EU funding, reinforced by performance and progress indicators.

6 Conclusion

Based on the findings, the Republic of Croatia plans to significantly expand its cycling infrastructure between 2023 and 2027. Roughly 879 km of improved infrastructure will be developed at the national and local levels, with a total of about EUR 87.5 million in planned investments. A comparison with recent project data indicates that the true construction costs of high-quality, physically separated cycling infrastructure may be significantly higher than current planning estimates, even though these investments represent a significant step toward strengthening the national cycling network. This emphasizes the necessity of thorough project prioritization, accurate cost estimates, and well-coordinated execution to guarantee that planned investments successfully support the creation of a continuous, safe, and strategically sound cycling network. Croatia has significant potential for cycling development, based on the findings, but there are limitations to structure with infrastructure dispersion, unequal quality, and poor integration. By creating a coherent national framework for infrastructure development, the suggested emphasis on a clearly defined network of major cycling routes offers a strategic approach to these concerns. Increasing the modal share of cycling and fulfilling greater sustainability objectives need improving continuity, safety, and functional hierarchy within the cycling network. While the projected investments are an important step forward, their efficacy will depend on institutional coordination, consistent standards, and integration with regional and urban mobility systems. In conclusion, the Republic of Croatia ought to consider the development of a national network of major cycling routes as a strategic investment in sustainable mobility, public health, and regional connection rather than just an infrastructure project.

Acknowledgment

This work and its presentation at the CETRA 2026 Conference were supported by the European Union – NextGenerationEU through the institutional research project at the University of Zagreb, Faculty of Transport and Traffic Sciences: Smart Traffic Network: Integration of LRS Model, Weibull Distribution, and AI for Decoding FCD Data (STN-AI).

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